Network Rail Interim Climate Change Adaptation Report
30 September 2010

1. Functions impacted by climate change

What are your organisation's functions, mission, aims, and objectives?

Network Rail is a not for dividend company that owns and operates Britain's rail infrastructure. Its mission is to provide a safe, reliable and efficient railway fit for the 21st century.

Network Rail operates under a Network Licence which sets out the conditions under which it must operate.

In particular, Licence Condition 1 sets out Network Rail's core obligations to secure the operation, maintenance, renewal and enhancement of the network in order to satisfy the reasonable requirements of persons providing services to railways and funders. This is in respect of the quality and capability of the network and the facilitation of railway service performance.
This condition also includes some specific obligations for Network Rail to:

- produce a delivery plan;
- establish and maintain route utilisation strategies (RUSs);
- develop policies and criteria demonstrating how it will meet the core obligations;
- maintain appropriate, accurate and readily accessible information about the relevant assets;
- co-operate with potential operators or funders on allocation of capacity;
- run an efficient and effective timetabling process; and
- asset management policies and criteria to maintain, renew, replace, enhance and develop the assets.

Which of these will be affected by the current and possible future impacts of climate change?

All the predicted incremental changes in the climate (e.g. longer, hotter, dryer summers and warmer, wetter winters) as well as increased frequency of extreme weather events (e.g. flooding and storms) will impact on the components of the rail system (i.e traction, services, staff, subsystems covering track, rolling stock, stations, depots, structures, electrification and signaling and other train control systems) and, consequently, most aspects of Network Rail's role, responsibilities and functions.

We are already working closely with our customers, industry partners and key other stakeholders to understand the likely impact of climate change on our infrastructure, and to mitigate and adapt to climate change and respond effectively to the threats, and also opportunities, that it brings.

In particular, Network Rail and the rail industry are focused on how the current and future climate will affect the ability to achieve and deliver:

- a safe railway;
- a highly reliable railway;
- increased capacity;
- value for money.

Network Rail has well established plans and procedures in place to both respond to extreme weather events and deliver appropriate levels of infrastructure resilience and service continuity under currently experienced weather patterns.

With regards to railway assets particularly, studies by Network Rail as well as the Rail Safety and Standards Board (RSSB) and the Environment Agency, for example, consider the impacts of climate change on coastal defences and flood-susceptible structures.

Network Rail is also embarking on further protection of railway assets, some of which are one hundred and seventy years old, from the impact of extreme weather conditions, by investing a substantial amount of capital expenditure for renewal work on railway drainage at priority locations

Our work on adaptation to date has highlighted the importance of prediction to facilitate the long-term management decisions required and to support the reliable operation of the railway through the maintenance, and modification or replacement of potentially vulnerable assets. The requirement for this is all the more important given the future demands and needs for a highly reliable railway, increased capacity and value for money.

The resistance and resilience of railway assets to current extreme weather events and to future climatic conditions, needs to lead to the assessment of the railway as a whole system. The development of a generic method for assessment of the future impact of climate change, will permit the development of options for managing railway assets in the longer term.

Such an approach will also needed to inform discussions between Network Rail and its regulator, on future infrastructure investment in the run up to government decisions on what outputs it wants the railway to deliver in the next five year regulatory period starting in 2014, known as Control Period 5 (CP5).

Has your organisation previously assessed the risks from climate change? Have you a baseline assessment of the risks of climate change to your business currently? (The requirements of the Direction can build upon any existing risk assessment you have in place. Please include a summary of findings from your previous risk assessment(s) in your report).

Network Rail has carried out various risk assessments or been involved in broader assessment projects including;

- Asset failures, which we report to our regulator;
- Delays due to asset problems which provide evidence for the development of risk assessments and thresholds;
- Asset risks caused by various climatic conditions produced for the Cabinet Office's natural hazards team for their work on critical infrastructure resilience;
- Network Rail asset assessments following extreme weather events such as flooding in 2007 and 2009 and the heavy, prolonged snow fall last winter;
- Analysis of passenger comfort in extreme weather event, leading to the development guidance and contingency plans, developed in partnership with train operators;
- Network Rail route specific extreme weather plans based on climate predictions (climate change impacts and thresholds may vary greatly according to geography and climatic conditions in different areas);

- Past and current Railway Safety and Standards Board (RSSB) studies, such as T925 Tomorrow's Railway and Climate Change Adaptation (TRaCCA)[1], work to support the TRaCCA project by the Met Office's Hadley Centre[2] and more specific projects, e.g. on T643 Impact of Climate Change on Coastal Rail Infrastructure[3];
- The International Union of Railways work stream on Adapting Railway Infrastructure to Climate Change (UIC ARISCC)[4];
- Network Rail Report - Climate Change - An Assessment of the Potential Impact of Flooding on Railways in the South West[5]
- EPSRC-funded FUTURENET research project on UK transport networks in the 2050s[6].

If so, how were these risks and any mitigating action incorporated into the operation of your organisation? (It is useful to understand whether, and to what extent climate change risks are already incorporated into your business risk management processes at the strategic level).

The understanding of potential climate change impacts has influenced our strategies for managing our operational assets. These strategies are defined in our asset management policies and define the inspection, maintenance and renewal regimes for each asset and are generally developed on a minimum whole life whole system cost basis. This involves consideration of the likely change in operating environment resulting from climate change and how this may impact upon the performance of the asset.

An example of this is in our approach to assets that may be affected by flooding, and guidance has been issued on this, which is based on our understanding of potential future rainfall and river flow rates. Clearly climate change is likely to have a more significant impact on assets with longer lives, such as bridges, earthworks, coastal defences and other large structures.

Future improvements in our understanding of climate change will obviously improve our ability to optimise our asset management policies. The recently published UK Climate Projections will provide an important input to this process.

Have you assessed the climate thresholds above which climate change and weather events will pose a threat to your organisation? If so what were the main results?

Phase 2 of the TRaCCA project involving Network Rail, the Association of Train Operating Companies (ATOC) and the Met Office, under the auspices of the RSSB, will report on climate related vulnerability thresholds for heat, precipitation, vegetation and sea level rise.

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[1] RSSB Study T925 (in progress) Tomorrow's Railway and Climate Change Adaptation, www.rssb.co.uk/SiteCollectionDocuments/pdf/reports/Research/T925_rb_final.pdf

[2] A Preliminary Report by the Hadley Centre on *"The impact of Climate Change on the rail network"* will be finalised on 30 September;

[3] RSSB Study T643 Impact of climate change on transport infrastructure, www.rssb.co.uk/SiteCollectionDocuments/pdf/reports/Research/T643_rpt_final.pdf

[4] International Union of Railways Research Project ARISCC (in progress); www.uic.org/baseinfo/projet/projet.php?id=207

[5] Internal Network Rail report Climate Change - An Assessment of the Potential Impact of Flooding on Railways in the South West; Prepared for the South West Regional Assembly Transport Officers' Subgroup, 2006

[6] EPSRC-funded research project FUTURENET, www.arcc-futurenet.org.uk/

The project has already delivered the following outputs;

a. Confirmation of priorities with infrastructure, TOC, maintenance and operations specialists
b. Confirmation of data availability: performance, safety data, rolling stock, systems, operations

Phase 2 of the project has produced and tested mathematical models that enable the quantification of the impacts of climate change for selected priority topic areas the project has identified (see below) for the decades up to the 2040s.

The Met Office's Hadley Centre are supporting phase 2 of TraCCA by work with Network Rail and other industry representatives to identify key meteorological thresholds at which industry impacts are felt and decisions made for the priorities identified in phase 1 (set out later in this report) and assess the changing frequency of their occurrence up to the 2040s (using the science that underlies the UK Climate Projections 2009).

This project has developed innovative techniques to combine climate model output with incident data to translate the findings into metrics commonly used across the industry to assist sector experts in developing business strategies for a changing world.

In Phase 3 the models will be utilised to calculate impacts on a route-by-route basis, and the outputs will be available in visual format. Other products from the TRaCCA project include;

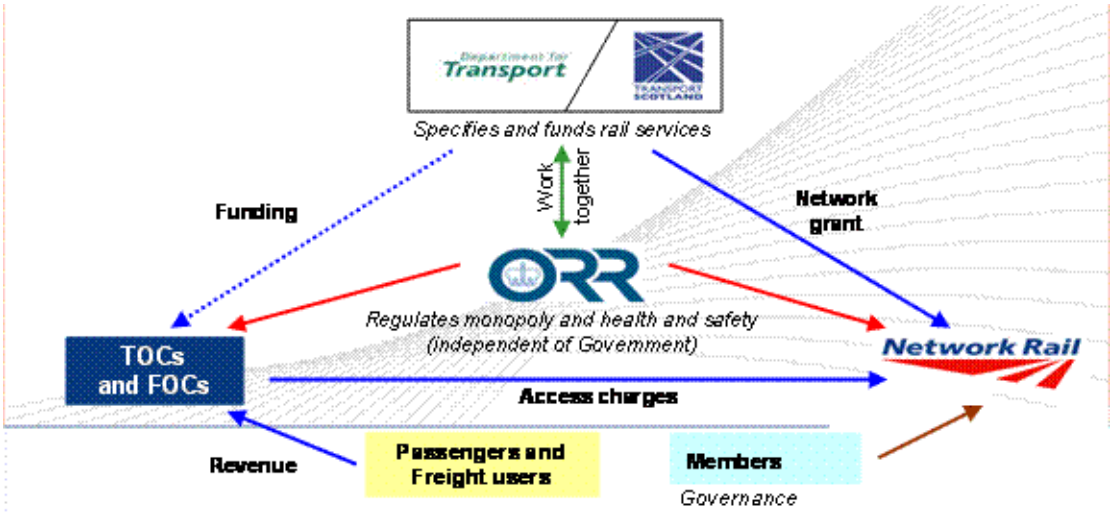
a. a tool to enable more detailed analysis of future policy options across a wider range of topics
b. dissemination of results via a rail industry event
c. publication of reports on the RSSB- website

Network Rail intends to obtain data from the 2009 UK Climate Impact Projections (UKCIP) study for use on its Geographical Information System (GIS) to identify particular climate threats and thresholds and their implications on all its routes.

In other initiatives, Defra and the Environment Agency (EA) are supporting Network Rail via the Flood and Water Management Act 2010 in identifying areas of surface water flood risks and opportunities, and in mapping fluvial flood risks. For example, rail assets are already included on EA flood maps.

Who are your organisation's key stakeholders? Do you need to assess the impacts of climate change on them?

Overview of Britain's rail industry



The figure above sets out Network Rail's key stakeholders. On adaptation, Network Rail's key stakeholders are;

- Passenger and freight operators (TOCs and FOCs) - our customers;
- The DfT and Transport Scotland – who specify and fund rail services;
- The broader supply chain – which will also need to adapt its products for the rail industry;
- The Office of Rail Regulation – that regulates Network Rail;
- Other government departments and agencies involved in climate change and a low carbon economy- such as Defra, the Environment Agency, the Cabinet Office and Business, Innovation and Skills;
- Local, regional and sub regional government - Network Rail works closely with sub national government on climate change adaptation and particular issues such as flooding and other extreme weather events..

Network Rail has been working closely with the rest of the industry to look at the impact of climate change on its TOC and FOC customers, passengers and freight users and the supply chain.

For example, the TRaCCA project has identified the priorities of the rail industry including train operators, while the FUTURENET research project involves, among others, Birmingham, Loughborough and Nottingham Universities, Network Rail, the Highways Agency, the IMechE, in a research project to provide a vision and tools to assess and plan for the resilience of transport systems in the future.

This places an onus on both us and our customers to work closely together to formulate joint adaptation and extreme weather emergency plans that can be adopted across Network Rail and the rest of the industry and help Network Rail to develop a clearer understanding of customer expectation.

As part of the TRaCCA process the rail industry has also recently come together with the Met Office to develop common methodologies for weather modeling related to rail-specific impacts.

Network Rail also hosts an industry wide seasons management conference every year for the wider industry and its supply chain to raise awareness of the continued challenges faced through seasonal and severe weather conditions. It provides an insight to the various methods used to address the effects of severe weather and also demonstrates strategic direction in all weather management.

We are also delivering a series of seminars and workshops across our routes with train operators, including visualisation exercises, in order to educate the industry of its long term implications and long term costs.

Network Rail is working closely with our European and global industry partners, for example through the International Union of Railways ARISCC project, to both share our adaptation experiences and standards and learn from efforts of railways in adapting to current climate conditions which might become ours in future. Network Rail has also established an Adhesion Working Group which is part of a wider European group with colleagues in Holland, Ireland, Denmark and Germany.

With regards to the government and rail regulator, negotiations will shortly begin for CP5 during which the government and ORR will put forward their requirement with regards to climate change and the development of the railway.

Network Rail also co-operates with other, interdependent transport and broader infrastructure providers such as TfL (in a series of meetings, we have shared our rail risk assessments which have, unsurprisingly, proved to be very similar and discussed our interdependencies), the Highways Agency, the Environment Agency, British Airports Authority, National Grid (Network Rail is represented on a high level forum with these organisations) and the water sector on interdependencies and to learn from best practice across various sectors and build joint plans and weather forecasting tools. This provides sectors an opportunity to share techniques and technological initiatives.

In consultation with providers of rail and other transport modes we have developed integrated adverse seasonal weather mitigation, adaptation and response strategies. For example, Network Rail has an agreement with the Highways Agency on share access to our weather stations and is also involved in a Greater London Assembly initiatives on the sharing of weather stations in the capital.

2. Approach

What evidence, methods and expertise have you used to evaluate future climate impacts? List sources and references

Network Rail uses a range of external and internal evidence sources to assess the likely future changes in the climate and the impact they will have on the operation of railway. Principally we are currently relying on;

- UKCIP09 data which will be integrated with Network Rail's GIS to map key risks on a route by route basis – www.ukcip.org.uk (see response above);
- UKCIP09 Wizard adaptation tool;
- Met Office Hadley Centre via a contract, to develop weather/ climate modelling through the TRaCCA project - http://www.metoffice.gov.uk/climatechange/, (the same data used in UKCIP);
- Internal Network Rail datasets such as earthwork, structures, track, drainage asset registers;
- Network Rail's risk management procedures and supporting registers such as those used for track buckle risk management, bridge scour risk management;
- Network Rail's safety hazard reporting systems;
- ATOC vehicle fleet reliability data (NFRIP);

- Design criteria for lineside equipment, including overhead (rail traction) power lines;
- Network Rail's GIS data on flood plain extent;
- Network Rail's Water and Earthworks Risk Model (WERM)
- The Rail industry Safety Management Information System (SMIS)
- The Meteo group provide weather forecasts for Network Rail through their RailCast service (www.meteogroup.co.uk/uk/home/services_for_business/transport/rail.html)
- Environment Agency flood risk mapping

In the light of the weather risks identified from these sources, Network Rail's engineering, operations and asset management teams have worked with the train operators to identify key rail system vulnerabilities that need to be prioritised. These are set out below.

How have you evaluated the costs and benefits of proposed adaptation options?

Network Rail's Interim Strategic Business Plan (ISBP), due to be published in June next year, as part of negotiations (known as Periodic Review 13 or PR13) for the next rail regulatory period from 2014 (CP5) will set out the programme of work we would wish to carry out to adapt our infrastructure to climate change in CP5 and the longer term. It will also set out the funding requirements needed in CP5 for this programme of work to be delivered.

A tool to help evaluate the costs and benefits of different adaptation policies is being developed in phase 3 of the TRaCCA project.

What evidence have you assimilated to inform your risk assessment? What has been your approach (quantitative, qualitative, scenario based)? What resource (£ / person / days) have been assigned to this assessment? Briefly summarise your approach – in house staff, professional advisors, research expertise?) and

The TRaCCA Phase 1 risk assessment involved cross-industry expert workshops to identify and prioritise weather risks and asset vulnerabilities, which were then prioritised for further analyses. In order to prioritise the issues raised in the workshops, three categories, of Safety Impact, Performance Impact and likely Negative Impact from Climate Change were used to give a priority ranking.

Three levels were used to rate the risks during the workshops (Low, Medium, High), which were given a number, 1, 2 or 3 respectively. The numbers against the risk categories were then multiplied to give a risk score..A threshold for risk score was established from expert opinion at the workshop in order to achieve a ranked list. Any risk area showing 'high' for safety was automatically included as a priority. The outputs from the scoring exercise were then reviewed and moderated by expert engineers, as a way of validating the risks against railway knowledge and to provide a reasonable number of areas for further analyses. This exercise was mostly an internal exercise with support from the Met Office at each of seven workshops; involving Network Rail in 181 person days and contract work involved at a cost of £110,000.

In terms of in house resources for climate change, Network Rail has a dedicated climate change adaptation engineer dealing with assets and a weather team, based in its Operations and Customer Services function, dedicated to overseeing Network Rail's climate predications and developing risk assessments, thresholds and mitigation and adaptation plans accordingly.

How does your organisation quantify the impact and likelihood of risks occurring? Provide here a brief summary of the methodological approach to quantification where this has been possible and your categorisation of likelihood and impact. State what criteria you have used to characterise the significance of the risks (high, medium, low, negligible) and how these have been derived. What level of confidence do you have in the analysis?
How do you quantify, or otherwise estimate or characterise the impact and likelihood of risks occurring at various points in the future?

Phase 2 of the TRaCCA project has produced and tested mathematical models that enable the quantification of the impacts of climate change for selected priority topic areas the project has identified (see below) for the decades up to the 2040s.

In Phase 3 the models will be utilized to calculate impacts on a route-by-route basis, and the outputs will be available in visual format.

It is intended to show the impacts of climate change generally quantified in terms of performance, in delay minutes and using an average cost per minute.

Levels of confidence in the results will be determined from the nature of the input data, limitations of the modelling packages and uncertainties in the climate projections; it is likely that upper and lower bounds to the impacts will be shown along with the mean values. The sensitivity of the system or asset to changes in weather will be very relevant.

What uncertainties have been identified in evaluating the risks due to climate change? Where are the key uncertainties in the analysis of the impacts of climate change and what impact do these have on the prioritisation of adaptation responses and risks for your organisation. How have these uncertainties been quantified and, in brief, what are the implications for the action plan?

Owing to the divergence of results in the UK Climate Projections after the 2040s, and to the 30-year planning horizon covered by the Rail Technical Strategy (RTS)[7], we believe it is currently inappropriate to examine climate impacts beyond the 2050s.

The TRaCCA project will inform both the next Regulatory Review and policy for CP5 and beyond, and the next RTS, being prepared under the auspices of the rail industry Technical Strategy Advisory Group (TSAG). The next RTS is due for publication in 2012.

Other uncertainties include the size and shape of the rail network up to 2050 and traffic patterns expected.

[7] Rail Technical Strategy, DfT 2007, http://webarchive.nationalarchives.gov.uk/+/http://www.dft.gov.uk/about/strategy/whitepapers/whitepapercm7176/railwhitepapertechnicalstrategy/pdfrailtechstrategyrts1.pdf

3. Summary of risks which affect functions, mission, aims, and objectives

a) **List all the organisations' strategic risks from climate change on a likelihood/consequence matrix – including thresholds where applicable.**
b) **What short and long term impacts of climate change have you identified and how are each factorged into the adaptation programme? Quantify the likelihood and consequences as far as possible (including an assessment of the level of confidence (e.g. high/medium/low) in the calculations) and disaggregate these risks to different locations where appropriate**
c) **What are your high priority climate related risks and why (stating level of impact to business, likelihood, costs and timescales)?**

The TRaCCA project has identified asset and operational risks to the company which are set out in below in tables 1, which sets out an overview of asset risks and their impact, and 2, which sets out our priority areas for action on assets and operations.

The TRaCCA project has prioritised assets and systems according to climate risks and their impact on safety and performance. This project has also identified areas that require detailed weather modeling to inform risk assessments.

Further rail industry analyses will be required to determine how climate change will impact upon the functioning of Network Rail and the rail industry, for example on planning the development of the network, human and financial resources, customer services, and on the timing of climate change-related decisions in these and other areas. .

Table 1 – overview of asset risks

Climate Impact Group	Risks	Safety Impact	Performance impact	Likely Negative Impact from Climate Change?	Long or Short Term?
Heat	Air conditioning failure in carriages	Low	Medium	High	Short
Heat	Track buckling	High	High	High	Long
Heat	Speed restrictions due to buckle risk	Low	High	High	Long
Heat	Use of heat watchmen for buckle risk	Medium	High	High	Long
Heat	Floating electrical earth caused by a low water level	High	High	High	Long
Heat	Reduced window of opportunity for work – renewal and maintenance - due to heat restrictions on track	Low	Medium	High	Long
Heat	Reduction in track quality due to less maintenance	Low	Medium	High	Long
Heat	Staff working conditions in hot weather	High	High	High	Long
Heat	Earthworks desiccation	Low	Medium	High	Long
Heat	Effect of heat on swing bridges	Low	Low	High	Long
Heat	Contact wire sagging at terminal stations	Low	High	High	Long
Heat	Reduced transformer life	Low	Low	High	Long
Heat	Solar gain affecting lineside equipment Signalling, Power, Telecoms	Med	High	High	Short
Increased rainfall	Increased flooding generally	Low	High	High	Long
Increased rainfall	Flooding at stations	Low	Medium	High	Long
Increased rainfall	Flooding at depots	Low	Medium	High	Long
Increased rainfall	Flooding affecting plant and equipment rooms	High	High	High	Short
Increased rainfall	Flooding caused by poor drainage and high water levels	Low	High	High	Long
Increased rainfall	Flooding at bridges – scour/ pressure/ obstruction damage	high	High	High	Long
Increased rainfall	Flooding in tunnels	Low	Medium	High	Long
Increased rainfall	Flooding - Track Circuitry/ Automatic Warning Systems/ Lineside cabinets and equipment	Low	High	High	Short
Increased rainfall	Pluvial (surface water) flooding	Low	High	High	Long
Increased rainfall	Increased rainfall causing high surface run off	High	High	High	Long
Increased rainfall	Rising ground water level	High	High	Medium	Long
Increased rainfall	Scour due to high river levels	Medium	High	High	Long
Increased rainfall	Cabinets	High	High	Low	Short
Increased rainfall	Safety of workforce in extreme flood conditions – watchmen at flood sites	Medium	Low	High	Long
Cold	Heave caused by freeze thaw	Low	Low	Low	Long
Cold	Rockfall caused by freeze thaw	High	High	Low	Long
Cold	Freeze thaw action on bridges	Medium	Low	Low	Long
Cold	Ice in tunnels	Low	Medium	Low	Short
Cold	Broken Rails	Medium	High	Low	Short

Cold	3rd rail ice and snow	Low	High	Low	Short
Cold	Snow and ice on the track	Low	High	Low	Short
Cold	Slips, trips and falls, ice & snow	Medium	High	Low	Short
Wind	Effect of wind on bridges and traffic on bridges	Low	Low	Low	Long
Wind	Effect on equipment (OLE, signal, telecomms) structures, station canopies etc	Low	Low	Low	Long
Wind	Effect of wind on freight trains	High	Medium	Low	Long
Wind	Lifting with crane in wind	Low	Medium	Low	Long
Wind	Change in direction and speed affecting trees	Medium	Medium	Low	Long
Wind	Contact wire/ pantograph	Low	Medium	Low	Long
Sea level rise and increased storminess	Sea defences	Low	Medium	High	Long
Insolation/ heat/ rainfall/ wind	Increase and change in vegetation type	High	High	Medium	Long
Insolation/ heat/ rainfall/ wind	Floral Adhesion	High	High	Low	Long
Insolation/ heat/ rainfall/ wind	Vegetation – Showing Clear When Occupied track circuitry from leaves	Medium	High	Low	Long
Insolation/ heat/ rainfall/ wind	Vegetation - Signal sighting	Medium	High	Low	Long
Wind	Trees growing on the lineside – obstruction risk	High	High	High	Long
Insolation/ heat/ rainfall/ wind	Loss of a safe Cess from vegetation encroaching	Medium	Low	Medium	Long
Insolation/ heat/ rainfall/ wind	Vermin – signalling	High	High	Low	Long
Increased humidity	Corrosion of rails	Medium	Low	Low	Long
Increased humidity	Corrosion of bridges	Low	Low	Medium	Long
Various	Incident Response	Low	Medium	High	Short
Various	Failed trains and impact on passengers	Medium	High	High	Long

Table 2 – Summary of asset and operational priority topics

Climate Impact Group	Cluster	Consequence
Heat	Track	Management of track buckle risk
Heat	Track	Reduced window of opportunity to carry out maintenance/ renewals work due to heat
Heat	People	Passenger health from train failure in extreme temperatures, including heat and cold
Heat	People	Impact on freight from train failure in extreme temperatures, including heat and cold
Heat	People	Staff working conditions, eg: use of heat watchmen
Heat	Power/ Signalling/ Telecomms	Sag in tethered overhead line systems at terminal stations
Heat	Power/ Signalling/ Telecomms	Heat affecting lineside equipment; specifically signalling and telecoms equipment
Heat	Power/ Signalling/ Telecomms	Floating electrical earth leading to stray earth currents caused by dry ground/ low groundwater*
Rainfall	Fluvial flood	Track and lineside equipment Failure
Rainfall	Groundwater flood	Track and lineside equipment Failure
Rainfall	Pluvial flood	Track and lineside equipment Failure
Rainfall	Fluvial flood	Scour and water effects at bridges
Rainfall	Fluvial flood	Scour at embankments due to high river levels and culvert washout
Rainfall	Fluvial flood	Safety of workforce carrying out inspections during an extreme flood event
Rainfall	Pluvial flood	Landslips
Rainfall	Fluvial flood	Accessibility of fleet and of maintenance depots
Insolation/ heat/ rainfall/ wind	Vegetation	Change in type, poor adhesion, and track-circuit non-activation
Insolation/ heat/ rainfall/ wind	Vegetation	Falling trees causing obstructions
Sea level rise and storms	Coastal and estuarine defences	Wave overtopping and flooding at defended coastal and estuarine railways

*Floating earth has been re-prioritised to a low priority, but will remain on the list for possible consideration
**Priorities will be subject to continuous review as detail emerges regarding the potential robustness of analysis based upon current climate projections and data availability

d) What opportunities due to the effects of climate change which can be exploited, have been found?

Awareness of(?) Climate change could offer Network Rail and the wider industry with both short and longer term benefits.

A short term example, is that awareness raising and training within Network Rail on sustainability issues, including mitigating and adapting to climate change, has already led to a greater appreciation of the way consume resources, such as water, is already leading to cost savings through out the industry.

In the longer term, through projects such as the FUTURENET project (and particularly our participation in workshops with Nottingham University on future travel patterns), Network Rail is looking to identify geographical areas that might benefit in some ways from climate change. For example, coastal areas may experience longer, warmer summers and this may lead to tourism and leisure opportunities and increased demand for rail, and perhaps reusing decommissioned routes or developing new lines, in the longer term. This is something that could be developed in the future with local authorities within their future travel and tourism plans.

The continued reduction of cold days in winter may also lead to more reliable infrastructure and operations and fewer accidents on the railway for staff and passengers in future, such as a reduction in slips and falls from icy platforms, station entrances and exits, depot access walkways and roads.

Network Rail and the rail industry envisages improvements in its sustainable management of assets, of both infrastructure and TOC fleet, in terms of reliability and costs. Adaptation activities are likely to provide the impetus to:

a. improve the reliability of rail assets sooner rather than later;
b. develop longer-term strategies that will recognise a need for a systematic approach on the timing of key decisions on policy, for the maintenance and renewal of assets;
c. promote the development of geographically-based standards and measures for weather resistance and resilience that promote consistency of approach and expectations;;
d. work more closely with other organizations such as the government departments and the Environment Agency, where common interests are apparent

Phase 2 of the TRaCCA project has been designed to look systematically at the opportunities presented by climate change, in areas such as the day-to-day operational management of the network.

4. Actions proposed to address risks
What are the adaptation actions for the top priority risks (stating timescales)?
How will the adaptation actions be implemented (stating level of responsibility, investment and timescales)?
How much do you expect these adaptation measures to cost and what benefits do you anticipate will result from them?
How much do you expect them to reduce risk by, and on what timescales?
How will you ensure the management of climate change risks is embedded in your organisation?

Addressing current and future risks due to climate change

Business function	Climate variable (e.g. increase in temp)	Primary impact of climate variable (e.g health)	Thresholds above which this will affect organisation	Likelihood of thresholds being exceeded in the future and confidence in assessment	Potential impact on organisation and stakeholders	Proposed action to mitigate impact	Timescale over which risks are expected to materialize and action is planned
Engineering (assets, structures and systems	Various - heat, cold, insolation rainfall, flooding, wind, sea level rise, storms, humidity, increase in extreme weather events	Priority areas for action (identified by TRaCCA); - track buckle risk (heat) - stray earth currents (dry ground) - track and lineside equipment failure (flooding) - Scour and water effects at bridges (flooding) - Landslips (flooding) - Coastal and estuarine defences (waves and floods)	Phase 2 of TRaCCA will produce mathematical models to determine thresholds up to the 2040s for priority topics.	It should be possible to accurately predict likelihood of thresholds being exceeded up to the 2040s, predictions beyond 2050 are currently difficult.	Safety, performance and reliability of the railway impacting on TOCs and FOC	- Route specific strategies and guidance - Rail industry design and weather capability standards - Guidance for Civils Assets for renewals and enhance-ments - TRaCCA phase 2 deliverables - Thresholds for priority areas for decades up to 2050 - set out quick wins in dealing with climate change including current weather patterns - Spec for a tool to enable industry to evaluate adaptation	- Align with CP5 negotiations (PR13) and long term planning framework - Weather capability draft standards by 2014, assess by 2019, programme to adopt from 2019 onwards

						and resilience options Phase 3- - Develop evaluation tool recommendations for geographically specific standards and research requirements to support this	
Operations and customer services	Various (see above) Flooding	Priorities identified by TRaCCA – - Passenger health and freight impact from train failure (temperature extremes) - Accessibility of fleet and maintenance depots (flood) Degradations related to	Phase 2 of TRaCCA will produce mathematical models to determine thresholds up to the 2040s for priority topics.	It should be possible to accurately predict likelihood of thresholds being exceeded up to the 2040s, predictions beyond 2050 are currently difficult.	Safety, performance and reliability impacting on TOCs and FOCs	- Rail industry weather capability standards TRaCCA phase 2 deliverable- - Cross industry seminar to raise awareness Phase 3 deliverable- - Route based climate change vulnerability maps - Interactive mapping visualization tool - Priority climate change impacts for the whole industry for decades up to 2050 and seminar, report and guidance on the findings. Route specific	Align with PR13 and longer term planning framework

		locality and specifics				mitigation and adaptation strategies Work with Roscos and TOC/FOCs on rolling stock resilience (e.g traction motors)	
Planning and development and Govt and Corporate Affairs	Various	Identifying adaptation requirements and securing sufficient resources to meet them in PR 13 negotiations for CP5. - Monitoring implement of Network Rail's adaptation reports and regulatory requirements			- Possible new legal and regulatory requirements	- Develop a adaptation report for Defra by 30/9/10 and adaptation elements of Interim Strategic Business Plan for negotiations with govt and ORR on funding for CP5 setting out climate change policies	Align with PR13 and longer term planning framework
Maintenance and asset management	Various	- Priority areas for action (identified by TRaCCA); - track buckle risk (heat) - stray earth currents (dry ground) - track and lineside equipment failure (flooding) - Scour and water effects at bridges (flooding) - Landslips (flooding) - Coastal and estuarine defences (waves and floods) - TRaCCA priorities-	Phase 2 of TRaCCA will produce mathematical models to determine thresholds up to the 2040s for priority topics.	It should be possible to accurately predict likelihood of thresholds being exceeded up to the 2040s, predictions beyond 2050 are currently difficult.		- Guidance for Civils Assets for renewals and enhance-ments - TRaCCA phase 2 deliverable- - Initial recommend ations for asset mangmnt policy and planning for CP5-8	Asset mangment policy and planning for CP5 -8

		- Reduced window of opportunity to carry out maintenance/ renewals work (heat) - Vegetation including change in type, falling trees, poor adhesion and circuit activation problems					
Enhancements and renewals (investment projects)	Various	Reduced time for enhancements and renewals (as with maintenance)					Align with PR13 and longer term planning framework
Safety and compliance	Various	- Safety and wellbeing of workforce carrying out maintenance and inspections (extreme weather, flood)					Align with PR13 and longer term planning framework
Financial and human resources	Various	Resources to monitor and implement adaptation plans, cover the costs and harness the benefits and opportunities of climate change					Align with PR13 and longer term planning framework

5. Uncertainties and assumptions
What are the main uncertainties in the evidence, approach and method used in the adaptation programme and in the operation of your organisation?
What assumptions have been made when devising the programme for adaptation?

The main uncertainties regarding evidence, approach and method as well as assumptions arise from the UKCIP projections that Network Rail is using to inform its adaptation progamme.

Evidence on the nature and impact of climate change becomes less certain the further the projections go out into the future. Projections beyond 2050 are currently

extremely uncertain and are based on a range of assumptions. We have collaborated with UKCIP to understand their methodology and data and the assumptions they have made in their long term future projections.

A work stream of the TRaCCA project focusing on the health and safety impacts of traveling customers and staff will assume some of the worst case scenarios up to 2050 in order to guide adaptation and emergency planning strategies.

6. Barriers to adaptation and interdependencies
What are the barriers to implementing your organisation's adaptation programme?

As set out previously, discussions will shortly begin for PR13, during which time Network Rail will set out its detailed plans for the railway in the next regulatory period, including how it plans to adapt the railway to climate change, in its ISBP... The Government will respond setting out the outputs it wants from the railway in Control Period 5, and the financial resources available to deliver them (known as the High Level Output Specification and Statement of Funds Available or HLOS and SOFA). This process will culminate in a Network Rail Delivery Plan which will set out agreed adaptation activities for CP5.

However, until these PR13 negotiations are complete Network Rail does not have certainty about regulatory requirements with regards to climate change adaptation and the extent to which funds are available to meet them.

What do you see as the key challenges to implementation of your action plan? How will these be resourced and addressed? Briefly, what additional work is required?

Adaptation measures may be recommended by the Action Plan and are likely to be a combination of soft (e.g. management processes) and hard (e.g. engineered resistance or resilience) measures. Implementing these will depend on the levels of funding available, which in turn will depend on the investment case being made.

Has the process of doing this assessment helped you identify any barriers to adaptation that do not lie under your control? Interdependencies may arise where others' actions are likely to impact on your ability to manage your own climate change risks. Briefly comment on where this is the case.

This assessment has led to wider understanding of interdependencies already apparent in some parts of the rail industry. For example, the implementation of the Flood and Water Management Act 2010 and its equivalent in Scotland, and the Cabinet Office's work in critical infrastructure resilience have highlighted cross-sectoral issues, issues that will become more significant as the climate changes.

How will these barriers be addressed?

Once PR13 negotiations are complete Network Rail will be in a position to deliver its adaptation activities, including the development of plans, standards and specifications and budgets, with more certainty. Our Defra reporting requirements will be fully integrated within this process.

Meanwhile Network Rail will continue to lead and participate in discussions across business sectors where appropriate.

What/who are the interdependencies (including the stakeholders stated in response to question 1d)?

As stated in response to 1d Network Rail's principal stakeholders are;

- Passenger and freight operators (TOCs and FOCs) - our customers;
- The broader supply chain – which will also need to adapt its products for the rail industry;
- The DfT and Transport Scotland – who specify and fund rail services;
- The Office of Rail Regulation – that regulates Network Rail;
- Other government departments and agencies involved in climate change and a low carbon economy- such as Defra, the Environment Agency, the Cabinet Office and Business, Innovation and Skills;
- Local, regional and sub regional government - Network Rail works closely with sub national government on climate change adaptation and particular issues such as flooding and other extreme weather events.

As set out already in this report, Network rail is engaged in a range of initiatives with its TOC and FOC customers, as well as the supply chain, to both understand our requirements from each other and jointly plan for and manage the impact of climate change on the whole industry going forward.

As set out above, Network Rail will also shortly begin PR13 negotiations with DfT, Transport Scotland and the regulator during which they will set out their requirements on adapting the railway to climate change and deliver a funded programme to meet them.

Network Rail is also working closely with other rail and transport providers, both in the UK and abroad, to share best practice and experiences of adaptation planning.

The railway also depends on other infrastructure providers, particularly highways (for example, to get railway staff to work) and energy providers (to provide energy for traction and power control systems and buildings), to operate the railway. Network Rail already works closely with these stakeholders in various critical infrastructure forums, convened by the Cabinet Office and Environment Agency (on flooding issues). Going forward, it should be possible to share the adaptation plans of interdependent infrastructure providers through these forums and develop joint plans, where necessary.

7. Monitoring and evaluation
How will the outcome of the adaptation programme be monitored?

This will depend on the approach being agreed as part of the PR13 regulatory review process, but would be likely to include a set of specific measures agreed between the ORR and Network Rail, covering a programme of work for CP5.

How will the thresholds, above which climate change impacts will pose a risk to your organisation, be monitored and incorporated into future risk assessments?

Climate change adaptation, and the TRaCCA project specifically, is already referenced in Network Rail's Corporate Risk Register which the company uses in identifying and managing risks.

Assuming a programme is agreed with the ORR, Network Rail would offer to ORR proposals for measures and a monitoring regime.

In practice, outcomes will be monitored and reviewed both internally, particularly by the Asset Information team, by our Principal Engineer (Climate Change) and our Operations Seasons Management Team, as well as externally, through our reports to Defra and our CP5 Delivery Plan for our regulator and the government (setting out adaptation plans up to 2019) that results from PR13 negotiations.

These reports will be agreed and monitored at the very highest levels of Network Rail.

Network Rail also expects to hold regular reporting power review meetings with DEFRA and Cranfield University and other stakeholders.

How do you propose to monitor the thresholds above which impacts will pose a threat to your organisation (including the likelihood of these thresholds being exceeded and the scale of the potential impact)? It is possible that the current risk appetite within your organisation will change on account of the climate change risks identified. How will this be monitored?

Assuming that TRaCCA provides data on priorities, and activities are agreed in the PR13 process and with ORR, more detailed studies are anticipated during CP5.

These studies would likely be on Route reliability and climate change, and will afford the opportunity to utilize, for example, better data, information and science that will be available. These studies would be able to recognise changes in impacts.

It is possible that Network Rail's risk appetite may change, and the Corporate Risk Register affords a vehicle to register such changes.

However, it is relevant that current information from UKCIP suggests that the signals of climate change may in many cases not be apparent until the 2020s. In such circumstances, it will be important not to over react too early to possible future circumstances. In this regard, Network Rail and its stakeholders may have to recognise, as referred to in our answer to 3d, that the timing of policy decisions is important; in this respect, many current concerns on what are low priority or non-core activities may be deferred for five or ten years or more.

How will the residual risks of impacts from climate change on your organisation and stakeholders be monitored?
How will you ensure that the management of climate change risks is firmly embedded in your organisation?

Network Rail already has various teams devoted to managing the impact of external influences such as weather, on its assets. These teams work to mandatory Standards and guidance which require regular asset inspections and special inspections during and after extreme weather events.

Assuming agreement is reached with the government and regulator on adaptation activities for CP5, Network Rail's resulting reporting and regulatory requirements will mean that the risks associated with climate change are monitored and managed at the highest levels of the organisation, and that Standards will be written and implemented to ensure an appropriate response to new risks; current risks being managed by existing Standards.

How will you enable your management of climate change risk to be flexible?

Flexibility is built into Network Rail's adaptation plans and processes given the uncertainties around the precise impact of climate change, discussed in this interim report, Network Rail's adaptation plans are formulated on the basis of a range of possible scenarios. Furthermore, our plans will be regularly reviewed and developed, not least because of our Defra reporting requirement, to enable us to response flexibly to new evidence and experience of implementing our plans.

Has the production of this report led to a change in your management of climate risks?

Yes. Network Rail already has various people and resources devoted to climate change activities, including a Principal Engineer for Climate Change and an Operations Seasons Management Team whose portfolio is under review. However, as has already been stated, Network Rail's reporting requirements to Defra, as well as forthcoming negotiations on PR13, have been very important in focusing attention on this issue in the company and also the broader industry and supply chain.

How will the benefits of the programme be realised and how will this feed into the next risk assessment and options appraisal? Briefly state your plans for the next iteration of your climate change risk assessment.

It is intended that the outputs from TRaCCA will inform both the PR13 process and the next RTS.

Feedback from this Report and the TRaCCA project will be used to develop further research needs, including the need for Route-based studies during CP5 towards an Adaptation Strategy triggering investment starting in CP6 lasting, perhaps, 20 years.

As has already been stated, Network Rail is working closely with the industry and other project partners on the benefits and opportunities of climate change, for example, in saving money and resources and generating new travel patterns.

The findings from work on benefits will be incorporated into future adaptation reports to Defra and incorporated into Network Rail's overall plans and the strategies of the particular functions they impact on, as appropriate.

For example, Network Rail's Planning function, which is responsible for planning the future development of the network, will look at the results of Network Rail's work with case studies at a national level and translate these for use within local authorities in how climate change will affect future travel patterns, e.g. increasing demand for leisure and tourism travel to British seaside towns as summers get longer and hotter.

The risk assessment is also expected to generate opportunities for organisations, have these been captured? What are the key ones and the expected net benefits?

TRaCCA has been designed not only to deliver quantified impact analyses for climate change and rail operations in the 2020s, 2030s, 2040s and 2050s but to:

a. Identify quick wins in the form of better understanding of current day weather issues. This can be used to identify early work on process or engineered resistance and reslience measures;

b. Run two seminars to raise awareness of climate change impacts across the rail industry, when industry partners will gain a better understanding on priorities, adaptation activities and timing;
c. Recommend geographically - based Standards development and further research requirements to support this approach. It is likely that economies in asset maintenance and renewal can be had through managing many assets according to how they behaves in their locality, rather than to national worst-case standard;
d. Guidance to inform the rail industry of likely climate change issues and how they will be dealt with, including what's less important and less significant;
e. Understanding of timing, such as where we can delay any action without compromising safety, performance or industry reputation.